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MINERAL PROFILING OF CHILLI PEPPER (*CAPSICUM ANNUUM* L.) INOCULATED WITH *COLLETOTRICHUM CAPSICI* (SYDOW), BUTLER AND BISBY

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ABSTRACT

Chilli pepper is among the world's most popular vegetable crop with a ranking of third after potato and tomato. Anthracnose caused by *Colletotrichumcapsici* can cause large losses to chilli. Experiments were done to determine if the mineral status of chilli is affected by infection with the anthracnose pathogen. Fruits of resistant and susceptible cultivars of inoculated and un-inoculated chilli pepper plants from six varieties/lines were collected in 2013 and 2014 and tested using nested design to determine their mineral/nutrient composition. There was variation ($p \leq 5$) in the mineral status among treatments group (inoculated & un-inoculated), type (resistant & susceptible) and in varieties/lines of the chilli plants due to the infection by anthracnose disease. Resistant type of plants expressed 2.81, 2.52, 2259,1185.50, 64.95, 179.60, 431.63, 141.12, and 110.58 while susceptible type showed 1.88, 1.66, 2562.67, 991.48, 35.40, 121.28, 140.87, 191.83,and 137.04 variation in concentration of nitrogen (N), phosphorous (P) (%), while potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), sodium (Na), iron (Fe), and copper (Cu) in ppm respectively. Resistant cultivars accumulated higher concentrations of these minerals compared to susceptible varieties and this increase in minerals in resistant host plants could help prevent the spread of pathogen by strengthening the biochemical and physiological processes of the host.

Keywords:*Capsicum annuum, Colletotrichumcapsici*, minerals, nested design, Solanaceae.

INTRODUCTION

Capsicum (*Capsicum annuum* Land *C. frutescens*L.) commonly known as chilli pepper is among the most popular vegetables of the world and is used for spices and condiments. Chilli pepper belongs to the Solanaceae family. The genus *Capsicum* is closely related to tomato, eggplant, potato, and tobacco. It is extensively used as a colorant in cosmetic products and is also valuable due to its nutritional and therapeutic properties. Moreover it is a good source of antioxidant compounds and is a component of many sauces. A wide spectrum of antioxidant vitamins, carotenoids, capsaicinoids, and phenolic compounds are present in chilli pepper fruit (Bosland and Votava, 2000). The consumption of these compounds in food is an important health-protecting factor by preventing widespread human diseases. Vitamins A, B, and C are found in abundant quantity in chilli pepper and it also contains an appropriate amount of minerals such as Fe, Ca, Mg, P, S, and K (Marin *et al*., 2004). For ornamental purposes, chilli peppers are cultivated also especially for their brightly glossy fruits with a wide range of colours Cronin (2002).

Production of chilli for spice, vegetables and other uses is increasing every year. It is estimated that chilli is annually cultivated on more than 1.5 million hectares in numerous countries, of which, about 46% is produced in Asia (with China the principal producing country). Southern Europe is the second most important chilli producing region with 24 percent of world production. Chillies are grown over an area of 62.7 thousand hectares with a total production of 150,300 tons in Pakistan (Anonymous, 2013).

Chilli is susceptible to several diseases including anthracnose caused by *Colletotrichumcapsici* (Sydow.) Butler and Bisby which poses a potential threat to chilli crop (Amusa, 2004). Chilli production has been severely affected by anthracnose disease which caused huge yield losses of up to 50 % in different parts of the world in the last fifteen years. The market and nutritive values in diseased infected fruits decrease, resulting in poor quality seed (Pakdeevaraporn *et al.*, 2005). About 17 % anthracnose infection due to *Colletotrichum* spp. has been reported recently by Haq *et al.*(2013) in the three districts of province Punjab (Pakistan).

Plant diseases can severely limit successful crop production and plant quality since they can decrease nutrient accessibility, uptake, distribution, or use by the plant. Nutrition influences all of the interacting components affecting disease severity. As part of the "environment," nutrients influence both plant and pathogen. The role of nutrition in these components is dynamic and all essential nutrients are reported to influence plant diseases. When a pathogen infects a plant, it disturbs the plant's physiology, including mineral nutrient uptake, absorption, mobility, and utilization. Some pathogens restrict the movement of nutrients in soil

or in infected tissues. They disturb the translocation or utilization of nutrients, inducing nutrient deficiencies or toxicities. Others pathogens utilize nutrients like N, P, K, Ca, Mg, Zn, Cu, and Fe in their growth, decreasing their availability to the plant and enhancing the plant's susceptibility to infection (Sahi *et al*., 2010). Strengthening the host plant health may help combat chilli anthracnose. An approach for the fortification of plant health is to study the elemental analysis of the diseased and disease free plants. The current study was undertaken to investigate biochemical changes with varying disease severities, as a base for resistance against the anthracnose pathogen. As such, a determination of the mineral contents (N, P, K, Ca, Mg, Zn, Na, Fe, and Cu) from the inoculated and un-inoculated plants of resistant and susceptible chilli cultivars was addressed.

MATERIALS AND METHODS

Test materials and experimental site: Seed of 6 varieties/lines (Sanam, C-72, Talhari, Gola peshawari, Tatapuri and Loungi) were collected from Ayub Agricultural Research Institute (AARI) Faisalabad. For nursery preparation, all varieties were sown into earthen pots (17 × 13 cm^2) containing one Kg of sterilized soil per pot**.** After about 50 days, the chilli seedlings were transplanted into plots at the experimental area of Department of Plant Pathology University of Agriculture, Faisalabad and grown on ridges with 60 cm × 30 cm spacing using a Randomized Complete Block Design (RCBD). Each entry was repeated three times. All agronomic practices were done as recommended by Agriculture Department including recommended number of irrigations and doses of fertilizers to keep the crop in healthy condition. At early flowering stage, inoculations were done with a 1×10^5 spores L^{-1} suspension of *Colletotrichumcapsici* which were measured with the help of Haemocytometer and were sprayed by using a sprayer in the evening and disease was confirmed by Koch postulates.

Determination of minerals status in chilli cultivars: Fruits of resistant and susceptible cultivars of inoculated and un-inoculated chilli plants were washed in 0.2% detergent solution to remove dirt, followed by washing in 0.8% HCL (to remove metallic contaminants from them) and deionized water (to remove previous two solutions). Samples were air dried, placed in paper bags, oven dried in at 70°C for 72 hours to get constant weight. The dried samples were ground with mortar and pestle. Then ground samples (100 mg) were boiled in 10 ml of 1.4N HNO_3 on a hotplate (TH-550; Advantec, Tokyo, Japan) 100 °C for 30 min. After cooling, the suspension was diluted 250 times with distilled water, followed by analysis for the determination of N, P, K, Ca, Mg, Zn, Na, Fe, and Cu following Bhargava and Raghupathi, (1995) method. Nitrogen and phosphorous contents were recorded on percent basis, while contents of other elements were recorded as ppm (parts per million).

Statistical Analysis: The plant populations were comprised of two groups i.e. inoculated and un-inoculated. Each group consisted of two reaction types: resistant and susceptible. Three resistant chilli varieties /lines were used: Sanam, C-72, Talhari, and the three susceptible varieties /lines were: Gola peshawari, Tatapuri, and Longi. Samples of inoculated and un-inoculated plants from resistant plants with disease incidence in the range of 11-24%and susceptible plants showing 76-80% infection were collected from the field area of Department of Plant Pathology during 2013 and 2014 and stored at 4°C. Standard analytical methods were used to estimate the minerals contents using a Nested Design (Gomez and Gomez, 1984). Statistical analysis was performed using PROC MIXED Procedure of the Statistical Analysis System (SAS, 2009). Data were analyzed statistically and treatments means were compared at $\alpha \leq 0.05$ through Duncan's multiple range test.

RESULTS

Determination of minerals contents of N, P, K, Ca, and Mg from inoculated andun-inoculated chilli plants: The samples of inoculated and un-inoculated plants from both resistant and susceptible plants were assessed for N, P, K, Ca, and Mg. Non-significant variation was observed between inoculated (averaging 2.27% across the inoculated group) and un-inoculated plants (averaging 2.56% across the un-inoculated group) indicating that N contents were not affected by disease status. The value 2.81% was observed across the resistant type and 2.03% across the susceptible significant at $p \leq 0.05$ (Table 1 and 2). The "type" component expressed a total variance of 79.66 %. Variety explained 19.60% of the total N variability (Table 1). The maximum amount of N was displayed by "C-72" variety at 3.075% and the minimum by "Gola peshawari" at 1.78% (Table 2). Regarding P contents, non-significant variation was observed between inoculated and un-inoculated plants (averaging to 1.96 and 2.22% respectively) during disease stress with no variation. With respect to P concentration, 88.65% of the total variance was between resistant (2.52%) and susceptible plants (1.66%) at $p \leq 0.05$, and 11.30% of the total variance was accounted for by variety. C-72 and Longi displayed maximum and minimum concentration of P at 2.77 and 1.54%, respectively (Table 1 and 2). Group and type exhibited 20.79 and 55.79 % of the total variability of K contents (Table. 1). Significant variation was attained by resistant and susceptible cultivars averaging 2259 and 2562.67 ppm respectively. Non-significant variation (2256.67 and

2565 ppm) was expressed by the un-inoculated and inoculated group under disease attack respectively. Gola peshawari variety showed maximum K fractions (2601.5 ppm) while minimum concentration was accumulated by Talhari (2215.5 ppm) at $p \leq 0.05$ (Table 2). Statistically significant variation was observed regarding Ca contents in group (averaging 836.68 ppm across the inoculated plants and 1330.32 ppm across the un-inoculated plants) as shown in table 1 and 2 accounting for total variance of 77.10%. Similarly, types had less variability of 9.42% (averaging 1185.50 ppm across the resistant plants and 991.48 ppm across the susceptible plants) as compared to group at $p \leq 0.05$. The varieties expressed significant variation as 13.47% of the total variance (Table 1). Ca concentrations of 1147.3, 1292.85, and 1116.35ppm were expressed by Sanam, C-72, and Talhari (resistant types), while 948.55, 1154.2, and 871.7ppm concentrations were expressed by the susceptible varieties Gola Peshawari, Longi, and Tatapuri, respectively as shown in table 2. Mg content was present in non-significant variation in both un-inoculated (63.18 ppm) and in inoculated plants (37.17 ppm) under disease stress condition with 17.80% of the total variability. Resistant and susceptible plants expressed significant variation (78.28%), averaging 64.95 ppm and 35.40 ppm, respectively. Varieties provided 3.21% of the total variance for Mg concentration. C-72 (69.5 ppm) and Tatapuri (33.20 ppm) displayed the maximum and minimum concentrations respectively (Table 1 and 2).

Determination of minerals contents of Zn, Na, Fe, and Cu from inoculated and un-inoculated chilli plants: Un-inoculated and inoculated plants expressed non-significant variation in Zn with no variance (Table 3). Similarly, non-significant variability in Zn of about 25.92% was observed in resistant (179.60 ppm) and susceptible plants (121.28 ppm). Zn concentrations of 261.05 ppm (maximum) and 118.10 ppm (minimum) were found for Sanam and Tatapuri which accounted for 74.08% of the variability (Tables 3 and 4). Na concentration had no variation in groups (averaging 274.78 ppm across the inoculated plants and 297.72 ppm across the un-inoculated plants) as shown in table 3 and 4. Significant variation (87.47%) was attained by resistant and susceptible cultivars averaging 431.63 ppm and 140.87 ppm respectively. The varieties expressed significant variation as 12.53% of the total variance. Talhari and Tatapuri showed 538.75 ppm and 133.25 ppm maximum and minimum Na concentration, respectively (Table 4). Group, type, and varieties expressed 29.07, 49.93, and 20.99% of the total variability in Fe contents (Table 3). Sanam (154.2 ppm) and Longi (200.29 ppm) gave the minimum and maximum concentration, respectively (Table 4). Cu contents varied significantly in both un-inoculated (137.04 ppm) and in inoculated plants (110.58 ppm) under disease stress conditions. Resistant and susceptible plants expressed 71.84% significant variation averaging 151.89 ppm and 95.73 ppm Cu, respectively. Varieties provided 25.17% of the total variance for Cu concentration. Sanam (173.03 ppm) and Longi (78.81 ppm) displayed their maximum and minimum concentration at $p \leq 0.05$, respectively (Tables 3 and 4).

Table1. Nested ANOVA for minerals (N, P, K, Ca, and Mg) of inoculated and un-inoculated chilli plants

SOV	DF	SS	F value	Pr>F	MS	Variance component	% of totalVariance component
Nitrogen (%)							
Group (A)	1	2.22	0.27	0.655	2.22	-0.11	0.00
Type (B)	2	16.40	13.14	0.003*	8.20	0.28	79.66
Variety (C)	8	4.99	239.85	0.000*	0.62	0.069	19.60
Error	96	0.25			0.0026	0.003	0.74
Total	107	23.87				0.35	
Phosphorous (%)							
Group (A)	1	1.82	0.19	0.709	1.82	-0.15	0.00
Type (B)	2	19.59	24.52	0.000*	9.79	0.35	88.65
Variety (C)	8	3.20	2037.66	0.000*	0.39	0.044	11.30
Error	96	0.019			0.0002	0.000	0.05
Total	107	24.63				0.39	
Potassium (ppm)							
Group (A)	1	1.64E+06	1.69	0.324	1.64E+06	12373.46	20.79
Type (B)	2	1.95E+06	12.43	0.004*	974892.30	33202.50	55.79
Variety (C)	8	627398.8	13.3aaw3	0.000*	78424.85	8060.32	13.54
Error	96	564673.4			5882.01	5882.01	9.88
Total	107	4.78E+06				59518.29	
Calcium (ppm)							
Group (A)	1	6.36E+06	12.087	0.074	6.36E+06	107973.49	77.10
Type (B)	2	1.05E+06	3.097	0.101	525891.25	13189.19	9.42
Variety (C)	8	1358270	10985.9	0.000*	169783.21	18863.08	13.47
Error	96	1483.63			15.45	15.46	0.01
Total	107	8767990				140041.21	
Magnesium (ppm)							
Group (A)	1	18536.50	1.45	0.352	18536.50	106.27	17.80
Type (B)	2	25594.12	72.45	0.000*	12797.06	467.42	78.28
Variety (C)	8	1413.03	41.15	0.000*	176.63	19.15	3.21
Error	96	412.10			4.30	4.29	0.72
Total	107	45955.75				597.15	

Table 2. Amount of N, P, K, Ca and Mg in reaction groups (inoculated and un-inoculated), types (resistant and susceptible) and in varieties/lines of chilli plants.

Nitrogen (%)												
Varieties (C)	**Sanam**		**C-72**		**Talhari**		**Gola peshawari**		**Longi**		**Tatapuri**	
Type (B)	**Resistant**						**Susceptible**					
Group (A)	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**
Amount of N in (C)	2.51	2.63	2.95	3.20	2.72	2.81	1.63	1.92	1.85	2.1	1.95	2.7

Av. amount of N in (C)	2.57		3.08		2.77		1.78		1.53		2.33	
Av. amount of N in (B)	Resistant = 2.81						Susceptible = 1.88					
Av. amount of N in (A)	Inoculated = 2.28						Un-inoculated = 2.56					
Phosphorous (%)												
Amount of P in (C)	2.17	2.42	2.65	2.89	2.38	2.58	1.51	1.69	1.31	1.76	1.71	1.97
Av. amount of P in (C)	2.30		2.77		2.48		1.60		1.54		1.84	
Av. amount of P in (B)	Resistant = 2.52						Susceptible = 1.88					
Av. amount of P in (A)	Inoculated = 1.96						Un-inoculated =2.22					
Potassium (ppm)												
Amount of K in (C)	2464	2119	2545	1995	2411	2020	2464	2119	2545	1995	2411	2020
Av. amount of K in (C)	2291.50		2270		2215.50		2601.50		2561		2525.50	
Av. amount of K in (B)	Resistant = 2259						Susceptible = 2562.67					
Av. amount of K in (A)	Inoculated = 2565						Un-inoculated =2256.67					
Calcium (ppm)												
Amount of Ca in (C)	944.1	1350.5	1005.1	1580.6	912.3	1320.4	775.1	1122.1	888.2	1420.2	555.3	1188.1
Av. amount of Ca in (C)	1147.3		1292.85		1116.35		948.55		1154.2		871.7	
Av. amount of Ca in (B)	Resistant = 1185.50						Susceptible = 991.48					
Av. amount of Ca in (A)	Inoculated = 836.68						Un-inoculated =1330.32					
Magnesium (ppm)												
Amount of Mg in (C)	45.2	75.6	50.2	88.8	47.6	82.3	26.2	40.3	30.3	49.2	23.5	42.9
Av. amount of Mg in (C)	60.4		69.5		64.95		33.25		39.75		33.20	
Av. amount of Mg in (B)	Resistant = 64.95						Susceptible = 35.40					
Av. amount of Mg in (A)	Inoculated = 37.17						Un-inoculated = 63.18					

Table3: Nested ANOVA for minerals (Zn, Na, Fe, and Cu) of inoculated and un-inoculated chilli plants

Zinc (ppm)							
SOV	**DF**	**SS**	**F value**	**Pr>F**	**MS**	**Variance component**	**% of totalVariance component**
Group (A)	1	3961.79	0.08	0.804	3961.79	-847.79	0.00
Type (B)	2	99485.03	2.05	0.191	49742.52	943.42	25.92
Variety (C)	8	194162.56	573794.7	0.000*	24270.32	2696.69	74.08
Error	96	4.06			0.04	0.04	0.00
Total	107	297613.44				3640.15	
Sodium (ppm)							
Group (A)	1	14018.59	0.012	0.922	14018.59	-20957.44	0.00
Type (B)	2	2.29E+06	21.94	0.001*	1.15E+06	40499.95	87.47
Variety (C)	8	417775.22	257290.4	0.000*	52221.91	5802.41	12.53
Error	96	19.49			0.2030	0.203	0.00
Total	107	2.72E+06				46302.56	
Iron (ppm)							

Group (A)	1	113520.58	2.021	0.291	113520.6	1062.25	29.07
Type (B)	2	112318.59	8.137	0.012*	56159.29	1824.35	49.93
Variety (C)	8	55214.26	20003.29	0.000*	6901.78	766.83	20.99
Error	96	33.12			0.345	0.345	0.01
Total	107	281086.54				3653.77	
				Copper (ppm)			
Group (A)	1	28896.99	0.762	0.475	28896.99	-167.18	0.00
Type (B)	2	75849.31	9.450	0.008*	37924.65	1255.98	71.84
Variety (C)	8	32105.28	76.98	0.000*	4013.16	440.11	25.17
Error	96	5004.44			52.13	52.13	2.98
Total	107	141856.02				1748.23	

Table 4. Amount of Zn, Na,Fe, and Cu in reaction groups (inoculated and un-inoculated), types (resistant and susceptible) and in varieties/lines of chilli plants.

					Zinc (ppm)							
Varieties (C)	**Sanam**		**C-72**		**Talhari**		**Gola peshawari**		**Longi**		**Tatapuri**	
Type (B)			**Resistant**						**Susceptible**			
Group (A)	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**	**Inoc.**	**Unin.**
Amount of Zn in (C)	272	250.1	157.98	145.91	115.9	135.76	99.1	150.9	110.71	130.75	110.70	125.5
Av. amount of Zn in (C)	261.05		151.95		125.81		125		120.73		118.10	
Av. amount of Zn in (B)	Resistant = 179.60								Susceptible = 121.28			
Av. amount of Zn in (A)	Inoculated = 144.39								Un-inoculated = 156.49			
					Sodium (ppm)							
Amount of Na in (C)	410	451.5	305	345.8	527.5	550	141	161.5	135.7	140.5	129.5	137
Av. amount of Na in (C)	430.75		325.40		538.75		151.25		138.10		133.25	
Av. amount of Na in (B)	Resistant = 431.63								Susceptible = 140.87			
Av. amount of Na in (A)	Inoculated = 274.78								Un-inoculated = 297.72			
					Iron (ppm)							
Amount of N in (C)	188.4	120	147.41	90.30	185.44	115.17	285.50	188.8	215.4	185.17	210.67	145.42
Av. amount of Fe in (C)	154.2		118.85		150.31		237.15		200.29		178.05	
Av. amount of Fe in (B)	Resistant = 141.12								Susceptible = 191.83			
Av. amount of Fe in (A)	Inoculated = 205.47								Un-inoculated = 140.81			
					Copper (ppm)							
Amount of Cu in (C)	144.5	201.53	142.43	153.47	120.4	148.97	90.33	103.53	70.3	87.32	95.51	127.40
Av. amount of Cu in (C)	173.03		147.95		134.69		96.93		78.81		111.46	
Av. amount of Cu in (B)	Resistant = 151.89								Susceptible = 95.73			
Av. amount of Cu in (A)	Inoculated = 110.58								Un-inoculated = 137.04			

DISCUSSION

Mineral nutrients affect in the development of plant diseases. The concentrations and forms of elements, type of disease and weather conditions are key factors which determine the effects of nutrients on disease development. The close relationship of the plant's nutritional status with pathogens is complex and dynamic, and hence, severity of most diseases can be greatly decreased by proper nutrients management (Vandermeer *et al*., 2010). The nutritional status of a plant also determines its histological or morphological structure and properties, which in turn controls the entry of pathogen, rate of penetration, and pathogenesis. Different kinds of nutrients may separately influence resistance/susceptibility of the host as well as a virulence/virulence of its pathogens and might naturally alter the ultimate outcome of their interaction (Bhaduri *et al*., 2014). Plants with balanced nutrition and all the required elements available in adequate amounts are likely to undergo less disease and may be better protected from fresh pathogen infection and able to limit existing infection better than plants which receive one or more of these elements in excessive or deficient amounts. Nutrient uptake is an essential process that affects plant growth. A remarkable effect of anthracnose disease of chilli on nutrition status of plant was observed in the present study (Spann and Schumann, 2010).

In plant tissues, N is a constituent component of many essential compounds such as proteins, amino acids, amides, nucleic acids, nucleotides, coenzymes, chlorophyll, cytosine and auxin (Lakitan, 2007). This nutrient becomes deficient due to run-off and leaching. Since plants require large amounts of N for normal growth, they respond most rapidly to applications of N (Spann and Schumann, 2010). Excess of N in soil favors some diseases while its deficiency also produce some others symptoms in plants (Dordas, 2008). The inoculated chilli cultivars contained less N in susceptible types while the un-inoculated and resistant chilli varieties contain more N contents. Outcomes of the present study are supported by the work of Jadon and Shah (2012) who described that resistant cultivars of bell pepper had higher concentrations of N as compared to susceptible varieties upon *Drechslera bicolor* infection.

P is utilized by the plants for the formation of nucleic acids, phospholipids, the coenzymes NAD and NADP, ATP and other high-energy compounds (Huber and Graham, 1999; Spann and Schumann, 2010). Improved root growth by P nutrition may allow the plant to escape attack by fungal pathogens (Prabhu *et al*., 2007). In the present study, the un-inoculated and inoculated plants in both resistant and susceptible group differed significantly with regard to P accumulation. Results of contemporary study aligned with the findings of Amusa *et al*., (2005), who observed variation in P contents between diseased and healthy plants.K has a major role in the activation of several enzymes that are involved in the metabolism of carbohydrates. K is effective in helping control plant diseases and pests. As a mobile regulator of enzyme activity, K is involved in essentially all cellular functions that control disease severity. The N balance with K significantly affects disease susceptibility of plants (Dordas, 2008). Furthermore, K influences tissue hardening, stomata opening patterns, photosynthetic rate, and infestation intensity (Huber and Graham, 1999; Rice, 2007; Spann and Schumann, 2010).We found that un-inoculated and resistant chilli cultivar accumulated less K concentration compared to the inoculated and susceptible chilli varieties, which agreed with the findings of Jadon and Shah, (2012). Plants suffering from K deficiency were easily lodged and sensitive to infection because the reduction in K level promotes disease severity in susceptible cultivars (Olanya *et al*., 2000). Na is absorbed by plants as Na^+ ions and its concentration greatly varied in the present study. Resistant and un-infected chilli varieties accumulated more Na concentration than susceptible and infected ones. Similar results were reported by Jadon and Shah, (2012) which confirm results of present study.

Ca is taken up by plants as Ca^+ cation and stimulates root and leaf development, microbial activity, and uptake of other nutrients. Ca helps with disease resistance for host plants and prevents penetration of pathogens. Ca is a structural component (as calcium polygalacturonates) of cell walls and membranes and also acts as a secondary messenger within the symplast in signalling pathways (Rice, 2007). As a major constituent of the middle lamellae in the form of calcium pectate, Ca plays an important role in maintaining cell integrity and membrane permeability (Spann and Schumann, 2010). Shortages of Ca cause disruption in cell structure, so plants become less able to resist infection caused by pathogens. In addition to providing a barrier, the cell wall regulates the passage of sugar and amino acids between cells (from the cytoplasm to the apoplast), but when Ca is low, it permits increased transport of sugars from within the cell to the intercellular spaces in the plant tissue stimulating the chances of infection and growth of disease pathogens (Marschner, 1995). A decrease in the concentration of Ca was observed in chilli plants infected with the anthracnose pathogen in the present study. Outcome of contemporary study is supported by the findings of Amusa *et al*., (2005). Mg also plays an important role in synthesis of chlorophyll and consequently in photosynthesis and carbohydrate metabolism (Devlin & Witham, 1983; Spann and Schumann, 2010). Increases in Mg contents were noticed in resistant cultivars compared to susceptible cultivars, which are in line with the findings of Jadon and Shah, (2012).

Zn nutrition appears to be involved in resistance to many diseases. The role of Zn in disease resistance is unclear but Zn acts as a co-factor for numerous enzymes (Rice, 2007). Zn application to soils reduces attack by root pathogens in many vegetable crops (Kalim *et al*., 2003). A significant variation in Zn concentration was found in chilli varieties where there was a low concentration of Zn in inoculated chilli varieties compared to un-inoculated one, which agreed with the report of Sahi *et al.,* (1999). Significant variability was observed in Fe, and Cu contents of resistant cultivars of both groups (inoculated and un-inoculated) upon infection with*Colletotrichumcapsici*. Findings of the recent study are supported by the observations of Mata *et al.,* (2001). These metals have direct toxic effects on plant pathogens and their deficiency decreases lignification in the xylem (Evans *et al*., 2007). Fe is a component of various flavoproteins (Metalloflavo proteins) which are involved in biological oxidation which increase as a result of inoculation with the pathogen. Fe acts as a co-factor in redox reactions and is also found in iron-prophyrn proteins, which include cytochromes, peroxidases and catalases. These proteins may be responsible for increased catabolic activities in susceptible plants (Devlin & Witham, 1983).

Conclusion: Reduction in host minerals (N, P, Ca, Mg, Zn, Na, and Cu) concentration was due to utilization of these nutrients by the pathogen for its growth and survival. Application of these nutrients is helpful in strengthening the biochemical and physiological processes of the host plant which help in enhancing resistance against anthracnose disease of chilli pepper.

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REFERENCES

Amusa, N.A., I.A. Kehinde and A.A. Adegbite. (2004). Pepper fruit anthracnose in the humid forest region of south-western Nigeria. Nut. Food Sci. 34(3): 130-134.

Amusa, N.A., A.O. Ashaye, M.O. Oladapo and M.O. Oni. (2005). Guava fruit anthracnose and the effects on its nutritional and market values in Ibadan, Nigeria. World J. Agric. Sci. 1(2): 169-172.

Anonymous, (2013). Fruits, vegetables and condiments statistics of Pakistan. Ministry of Food, Agriculture and Livestock, Federal Bureau of statistics, Islamabad.

Bhaduri, D., Rajiv Rakshit and K. Chakraborty. (2014). Primary and Secondary Nutrients-a Boon to Defense System against Plant Diseases, International J. Bio-resource and Stress Management, 5(3): 461-466.

Bhargava, B.S. and H.B. Raghupathi. (1995). Analysis of plant materials for macro and micro nutrients. In. Methods of analysis of soils, plants, waters and fertilizers. H.L.S. Tandon (Eds), Int. Res. J. Chem. 61-62.

Bosland, P.W. and E.J. Votava. (2000). Peppers: vegetable and spice capsicum. Crop production science in Horticulture. CAB Int. pub.wingfield England, U.K.P.204.

Cronin, J.R. (2002). The chilli pepper pungent principle: Capsaicin delivers diverse health benefits. Alt. Complemen. Therap. 8: 110-113.

Devlin, R. M. and F. H. Witham(1983). Plant Physiology. Wardsworth Pub. Co., California, USA. P.577

Dordas, C. (2008). Role of nutrients in controlling plant diseases in sustainable agriculture, A review, J.Agron. Sustain. Dev. 28: 33-46.

Evans, I., E. Solberg, and D. M. Huber. (2007). Copper and Plant Disease. In Mineral Nutrition and Plant Disease, edited by L. E. Datnoff, Wade H. Elmer and D. M. Huber, 177-188. St. Paul, Minn: American Phytopathological Society.

Gomez, K. A. and A. A. Gomez **(**1984**).** Statistical Procedures in Agricultural Research**.** New York, Chichester, Wiley. 2nd Ed. P 680.

Haq, I.U., S. Muhammad, S.A. Khan, M.J. Jaskani and Z. Ullah. (2013). Occurrence of Guavaanthracnose in Punjab (Pakistan) and its integrated management. Pakistan J. Agric. Sci.50(4): 707-710.

Huber, D.M. and R.D. Graham, (1999). The role of nutrition in crop resistance and tolerance to disease. In: Rengel, Z., (Ed.), Mineral Nutrition of Crops Fundamental Mechanisms and Implications. Food Product Press, New York, 205-226.

Jadon, K.S. and R. Shah. (2012). Effect of *Drechslera bicolor* Infection on physiology of Bell Pepper. J. Pl. Pathol. Microbiol. 3(4): 126-129.

Kalim, S., Y.P. Luthra and S.K. Gandhi. (2003). Cowpea root rot severity and metabolic changes in relation to manganese application. J. Phytopathol. 151: 92-97.

Lakitan, B. (2007). Fundamentals of plant physiology. Raja GrafindoPersada. Jakarta. Indonesia.

Marin, A., F. Ferreres, F.A. Tomas-Barberan and M.I. Gill. (2004). Characterization and quantification of antioxidant constituents of Sweet pepper (*Capsicum annuum*L.). J. Agric. Food Chem., 53: 3861-3869.

Marschner, H., (1995). Mineral Nutrition of Higher Plants, 2nd Ed. Academic, London, 889p.

Meta, C. G., L. Lammatina and R. O. Cassia. 2001. Involvement of iron and ferritin

Phytophthorainfestans interaction. Eur. J. Pl. Pathol. 107: 557-562.

Olanya, O. M., R. El-Bedewy, P. S. Ojiambo, P. T. Ewell and J. J. Hakiza. (2001). Relationship of fungicide application to late blight development and potato growth parameters in the tropical highlands of Uganda and Kenya.77–86. In: The International Potato Center 2003, Scientist and farmer partners in research for the 21st century, program report 1999–2000, Lima, Peru. P 480

Pakdeevaraporn, P., S. Wasees, P.W. Taylor and O. Mongkoloporn. (2005). Inheritance of resistance to anthracnose caused by *Colletotrichumcapsici* in *Capsicum annuum*L.. J. Pl. Breed. 124: 206-208.

Prabhu, A. S., N. K. Fageria, D. M. Huber, and F. A. Rodrigues (2007). Potassium and PlantDisease. In Mineral Nutrition and Plant Disease, edited by L. E. Datnoff, Wade H.Elmer and D. M. Huber, 57-78. St. Paul, Minn: American Phytopathological Society. ??

Rice, R. W. (2007). The Physiological Role of Minerals in Plants. In Mineral Nutrition and Plant Disease, edited by L. E. Datnoff, Wade H. Elmer and D. M. Huber, 9-30. St. Paul, Minn: Am. Phytopathol. Soci.

Sahi, S. T. (1999). Determination of some Morphological and Biochemical characters of lentil (*Lens culinaris*Medik.) for resistance against Ascochyta blight. P 133

Sahi, S.T., M.U. Ghazanfar, M. Afzal, W. Wakil and A. Habib. (2010). Influence of inoculation with *Aschochytalentis* on mineral contents (Na, Ca, Mg, Zn, Cu and Fe) of susceptible and resistant lines of lentil (*Lens culinaris*Medik.). Pakistan J. Bot., 42(1): 375-382.

SAS Institute Inc. (1990) "SAS Procedures Guide,. Version 9.3, Third Edition," Cary, NC: "SAS Programming Tips: www.ats.ucla.edu/ STAT/ SAS/ library/ nesug00/ bt3005.

Spann, T.M. and A.W., Schumann. (2010). Mineral Nutrition Contributes to Plant Disease and Pest Resistance. Series No.HS1181, Horticultural Sciences Department, UF/IFAS Extension, University of Florida, Gainesville, FL.

Vandermeer, J., P.,Ivette and P. Stacy. (2010). Ecological Complexity and Pest Controlling Organic Coffee production: Uncovering an Autonomous Ecosystem Service.Biosci. 60 (7): 527-37.